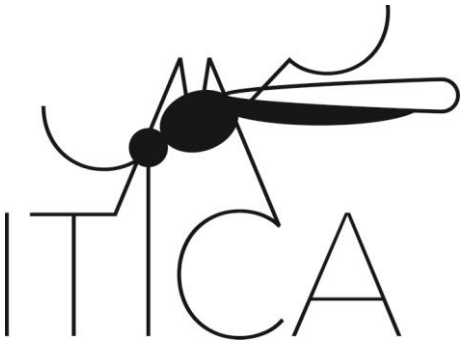
FINNISH METEOROLOGICAL INSTITUTE

Temperature-dependence of aerosol optical depth over the southeastern US?



The Living Planet Fellowship

Tero Mielonen, A. Hienola, T. Kühn, J. Merikanto, A. Lipponen, T. Bergman, H. Korhonen, P. Kolmonen, L. Sogacheva, D. Ghent, A. Arola, G. de Leeuw, H. Kokkola,

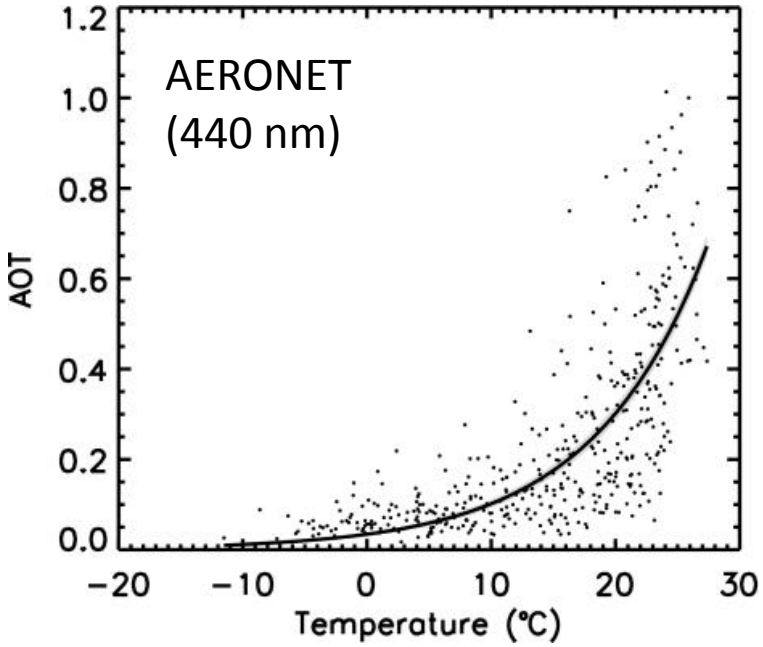
Today's menu

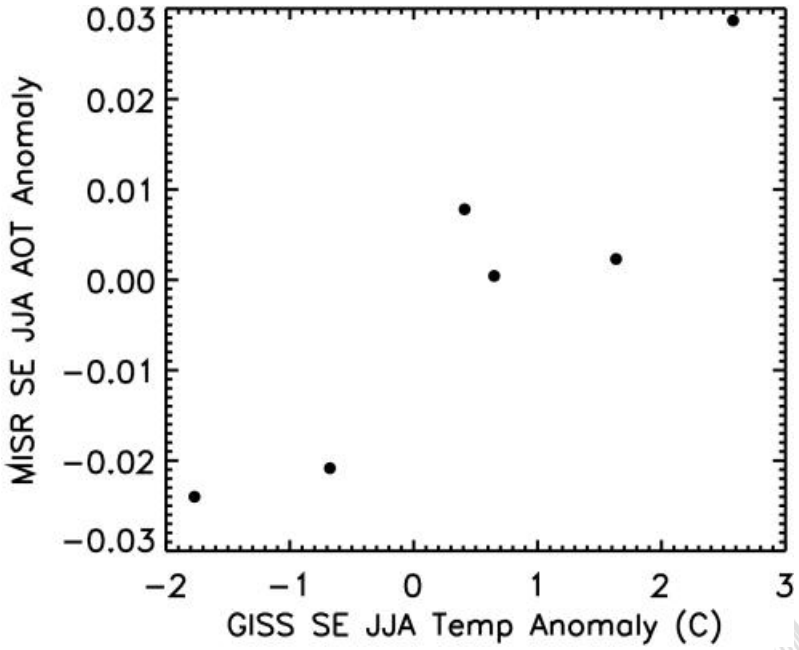
- **Background**
  - Does **I**ncreasing **T**emperature **I**ncrease **C**arbonaceous **A**erosol Direct Radiative Effect over Boreal Forests?
- **Overview of the project**
- **Results**
  - Spaceborne observations
  - Climate model analysis

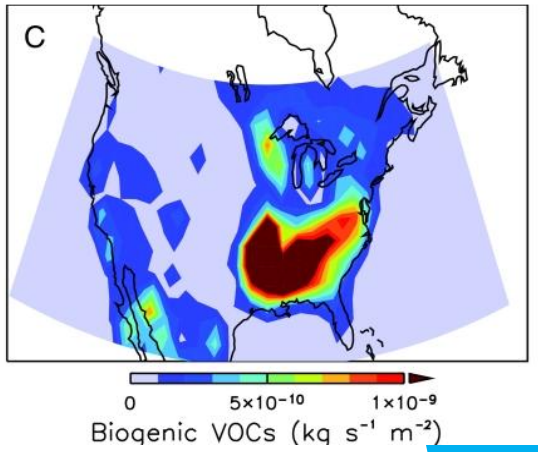
Background

Goldstein et al. (2009):

- SE U.S. has a strong seasonal AOD cycle
- seasonality matches BVOC emissions
- climatically relevant with significant potential for a regional negative climate feedback







Goldstein et al., Biogenic carbon and anthropogenic pollutants combine to form a cooling haze over the southeastern United States, PNAS, 2009.

Objectives

estimate the effect of increasing temperatures on the aerosol direct radiative effect

- investigate the causes of the positive correlation between AOD and LST
    - over the Southeastern US (Goldstein et al. 2009)
    - over boreal regions (Paasonen et al. 2013)
    - possible candidates:
        - BVOCs (increased by herbivores?)
        - Secondary organic aerosols (SOA) formed in aqueous phase
        - Biomass burning aerosols

- estimate the significance of the negative feedback caused by a warming-induced increase in the aerosol direct radiative effect

Satellite products used in the project

(2003-2011, Level 3)

- AATSR Land surface temperature (LST): 200 GB (1.4 million files!)
- AATSR Aerosol Optical Depth (AOD): 10 GB
- AIRS Carbon Monoxide (CO): 1.4 TB
- Soil moisture (CCI): 3 GB
- OMI Nitrogen Dioxide (NO2): 30 GB
- OMI Formaldehyde (HCHO): 140 GB
- SCIAMACHY Fluorescence (FSC): 0.5 GB

All products collocated to a daily, 1x1 degree grid

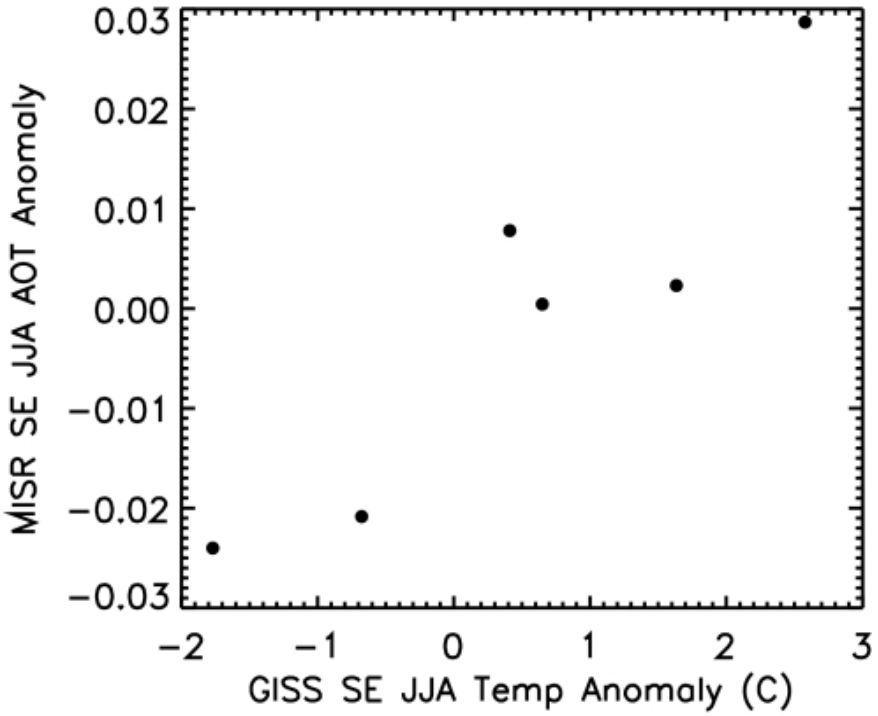
Model simulations done in the project

(2002-2010)

- Four simulations with ECHAM6.1-HAM2.2-SALSA (about 3 TB each!)
    - CONTROL
    - noBB: without biomass burning emissions
    - noSOA: without biogenic SOA formation
    - noAQSOA: without SOA formed in aqueous phase

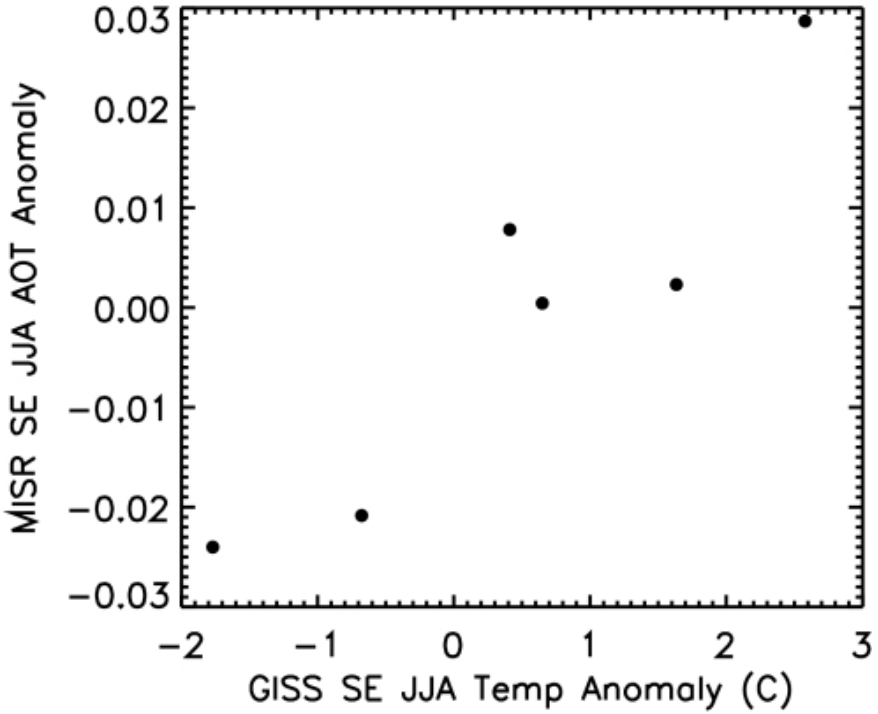
T63 grid (~1.9 x 1.9 degrees), daily or 3-hourly outputs

Results:
AOD vs. Temp



Goldstein et al. (2009)
Years 2000-2005

Results:
AOD vs. Temp



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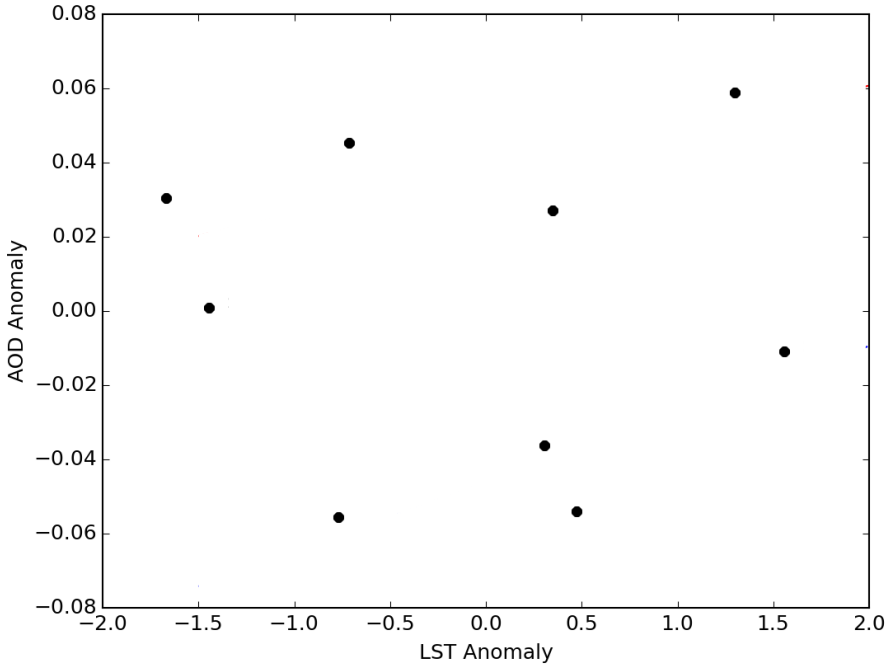
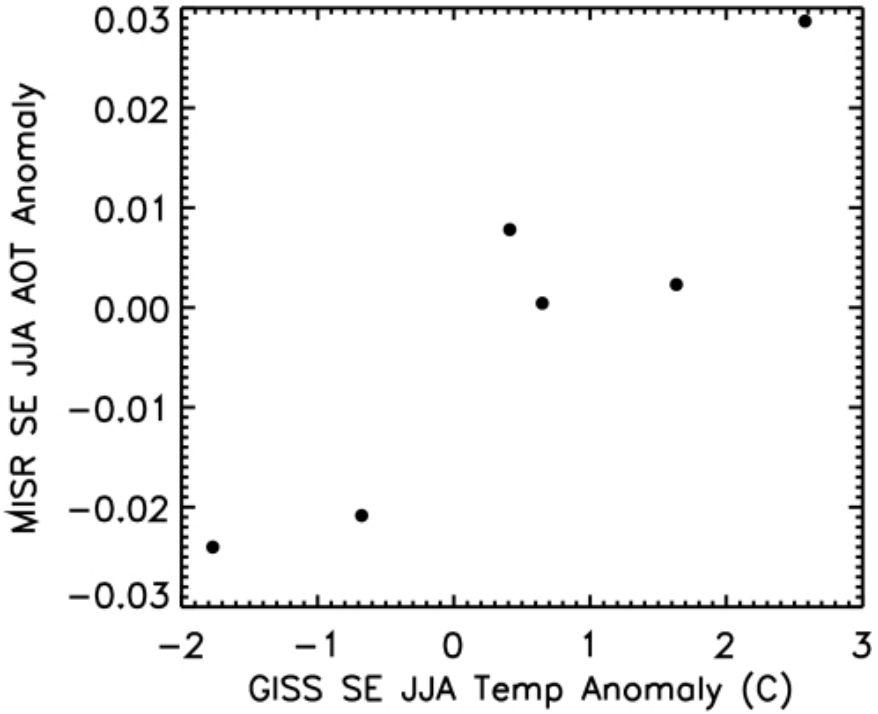


AATSR data (JJA)
Years 2003-2011

Results:
AOD vs. Temp



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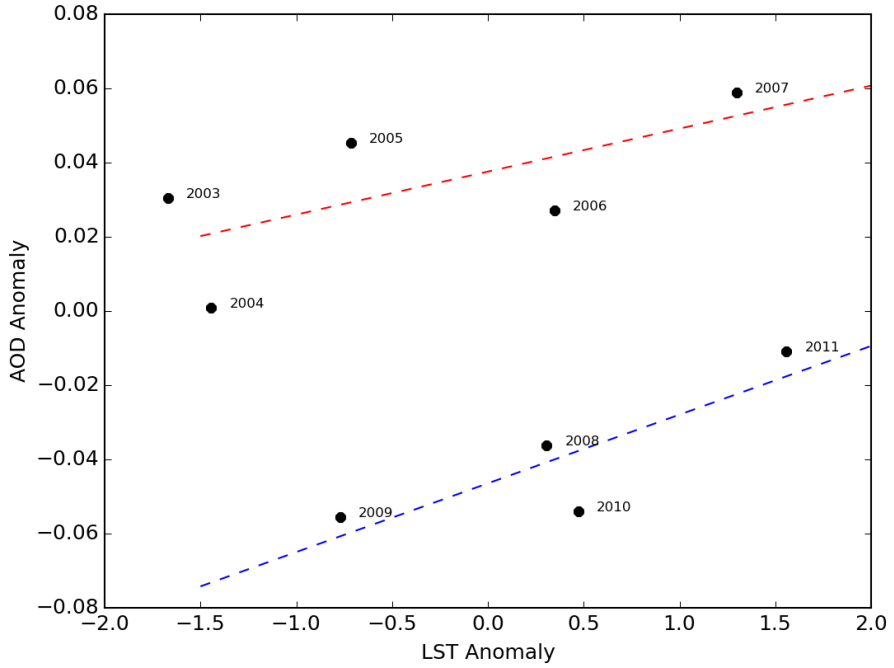
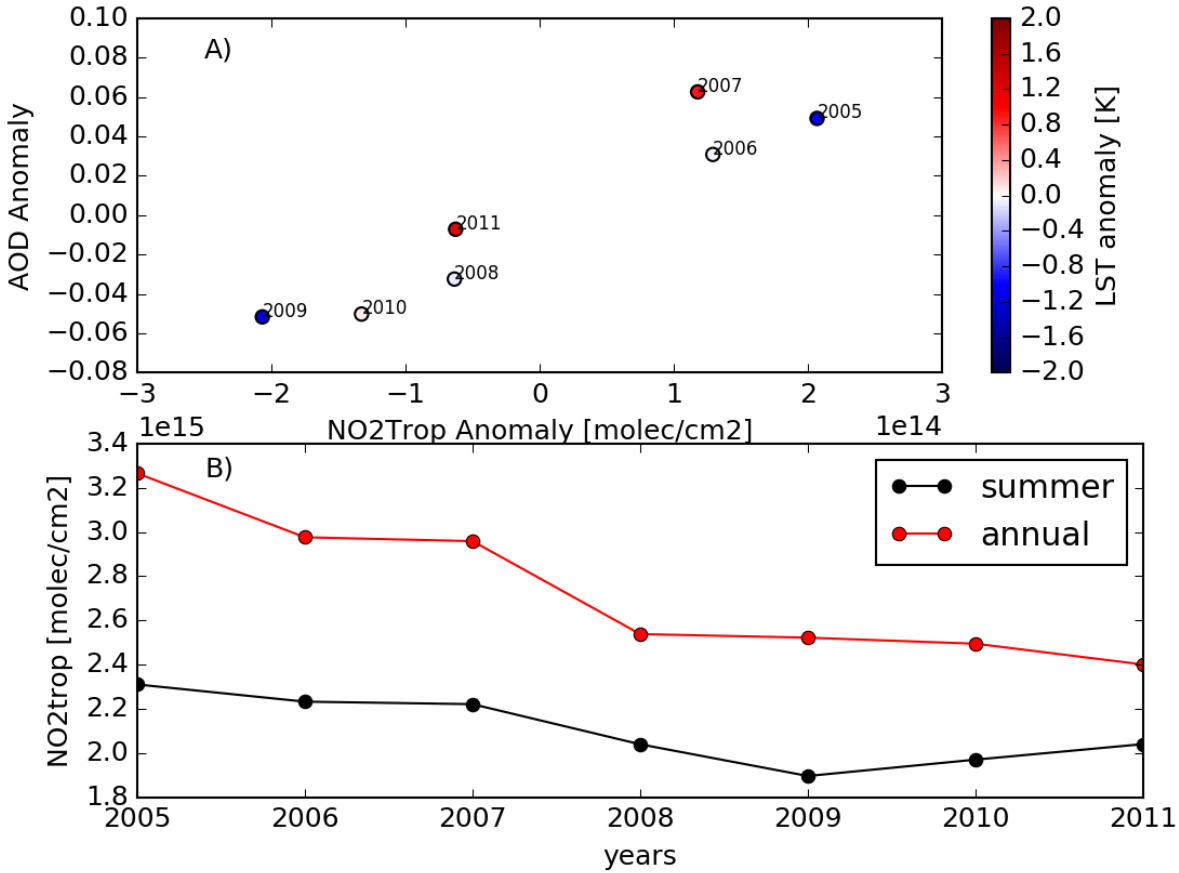


AATSR data (JJA)
Years 2003-2011

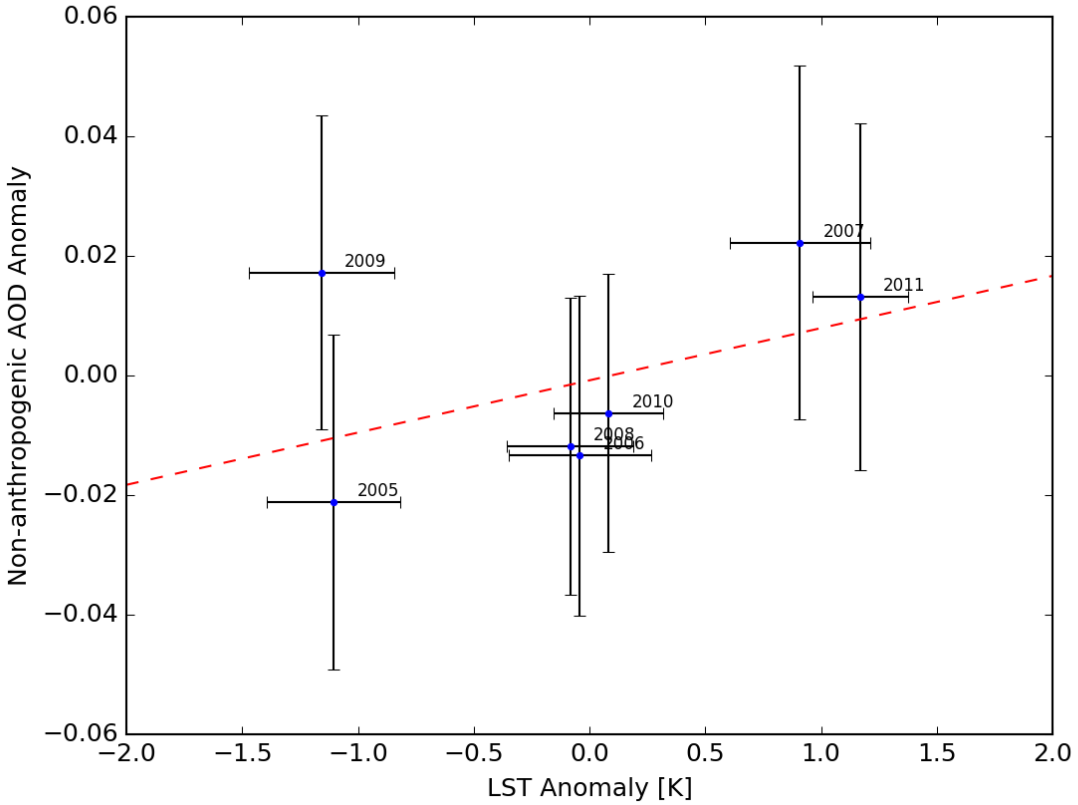
Results:
AOD vs. tropospheric NO2



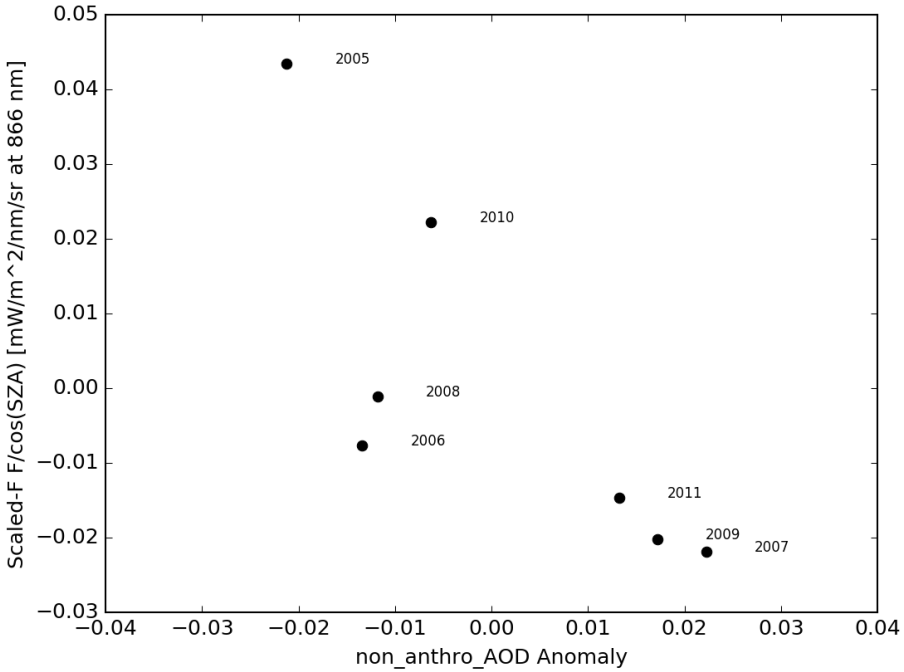
Results:
”Non-anthro” AOD vs. Temp

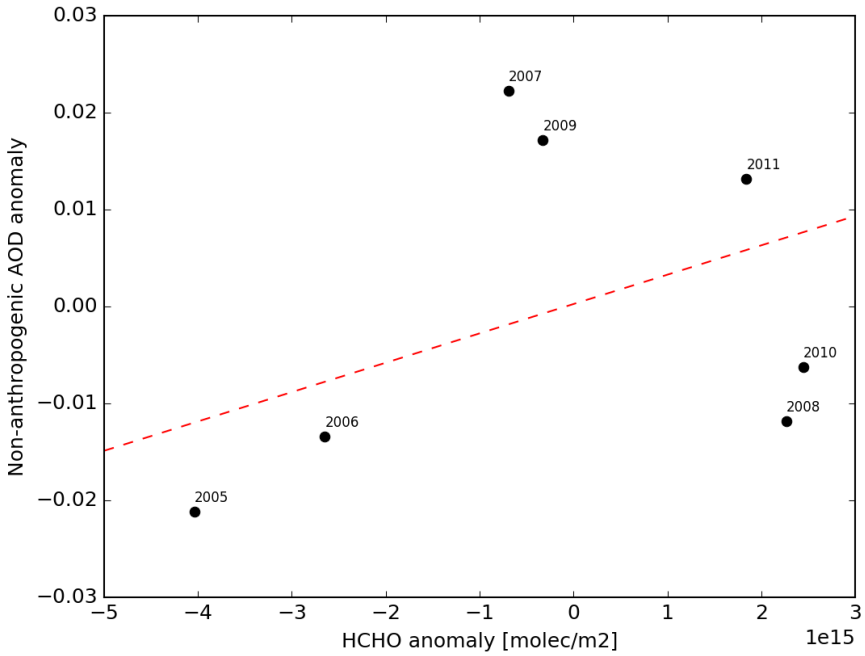
Calculation of “non-anthro” AOD:

- anthropogenic contribution was estimated with a linear fit between the summertime AOD and tropospheric NO_2 columns ($AOD=3.37e^{-16}NO_{2,trop}-0.414$)
- with this relationship the anthropogenic AOD was estimated from the observed tropospheric NO_2 values
- the “non-anthro” AOD was estimated by subtracting the anthropogenic AOD from the total AOD

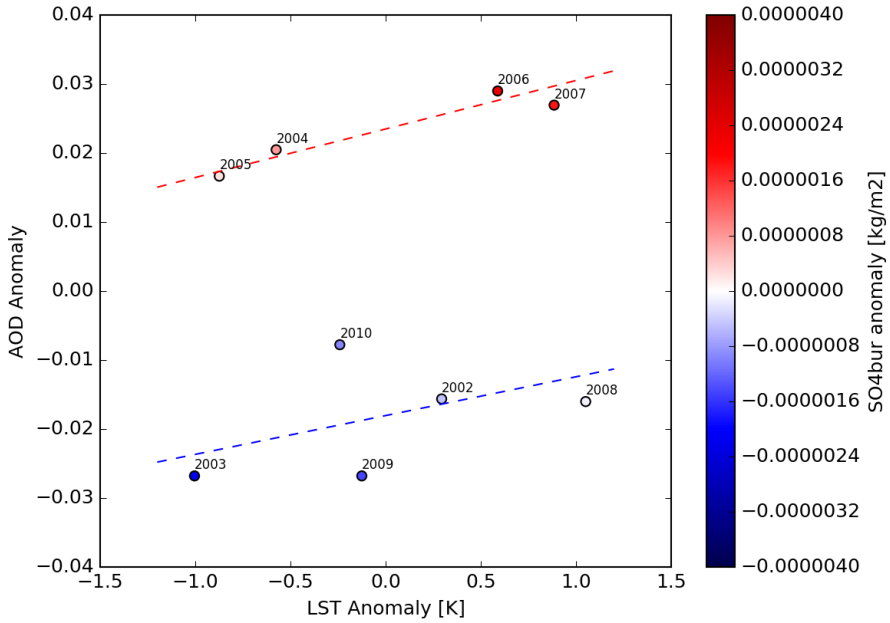


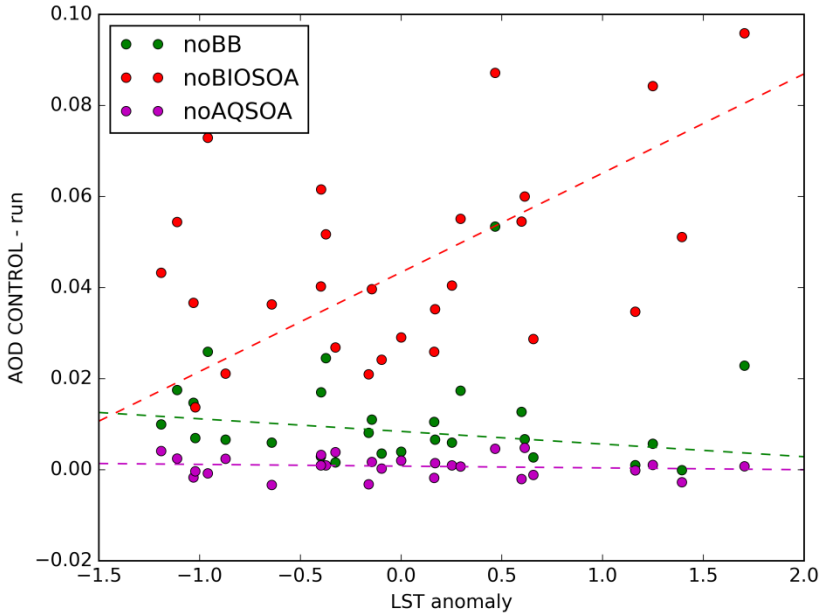
Results:
biogenic contribution?





Results:
Model comparison





Conclusions

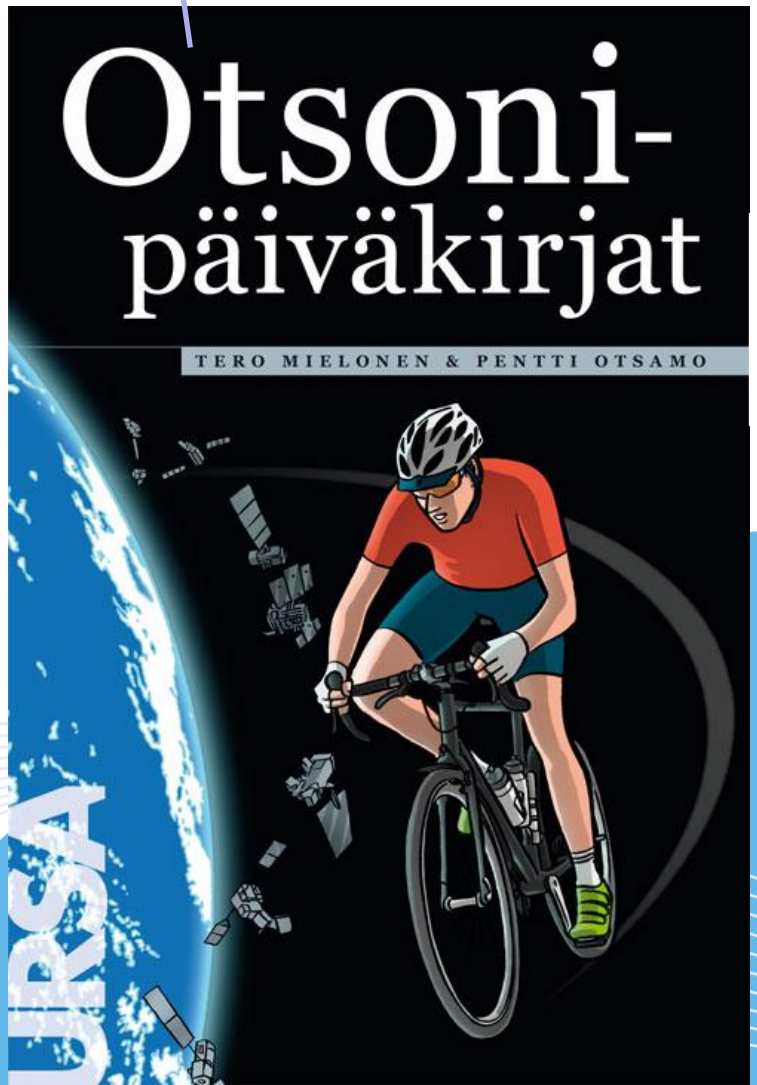
- the “non-anthropogenic” contribution increases AOD by approximately $0.009 \pm 0.018\ K^{-1}$ while the modelled BVOC emissions increase AOD by $0.022 \pm 0.002\ K^{-1}$

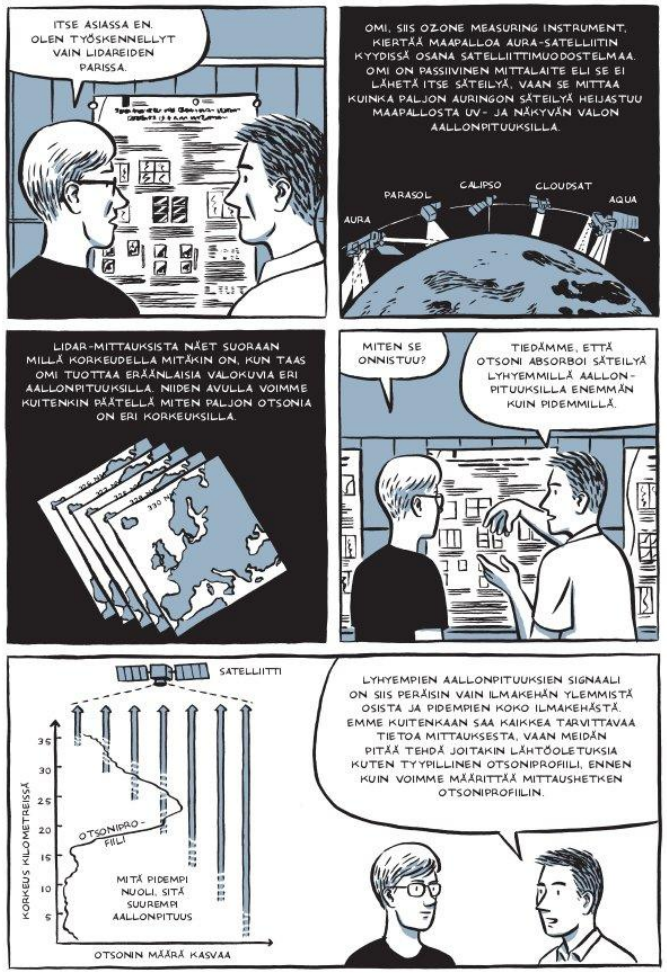
- regional direct radiative effect (DRE) of the “non-anthropogenic” AOD is $-0.43 \pm 0.88\ W/m^2/K$ (clear sky) and $-0.17 \pm 0.35\ W/m^2/K$ (all-sky)

- The model estimate of the regional clear-sky DRE for biogenic aerosols is −0.86 ± 0.06 W/m2/K.

Thank you!

”Ozone diaries”





Radiative effect calculations

$$DRE = S_{rad}\phi AOD(1-C_c)T_{atm}^2(1-R_s)^2\left(2R_s\frac{1-\varpi}{(1-R_s)^2}-\beta\varpi\right)$$

S_{rad} = incident solar radiation (461 W/m^2) at the top of the atmosphere
ϕ = mean daytime value of the secant of the solar zenith angle (1.33)
C_c = fractional cloud amount (0.0 for clear-sky and 0.6 for all-sky)
T_{atm} = aerosol free atmospheric transmission (0.76)
R_s = surface reflectance (0.15)
ω = single scattering albedo (0.972)
β = up-scatter fraction (0.21)

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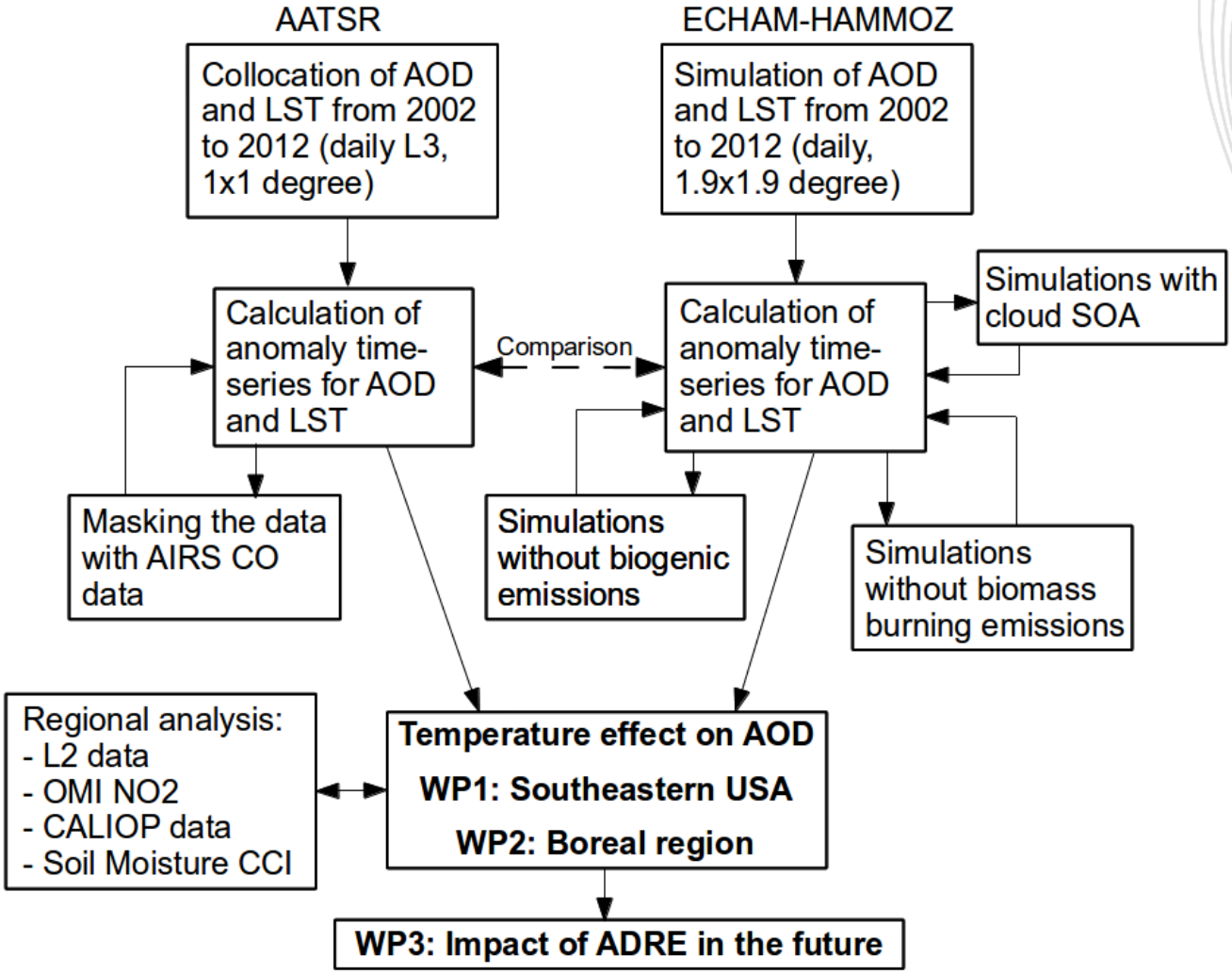
AATSR
ECHAM-HAMMOZ
Collocation of AOD and LST from 2002 to 2012 (daily L3, 1x1 degree)
Simulation of AOD and LST from 2002 to 2012 (daily, 1.9x1.9 degree)
Calculation of anomaly time-series for AOD and LST
Comparison
Calculation of anomaly time-series for AOD and LST
Simulations with cloud SOA
Masking the data with AIRS CO data
Simulations without biogenic emissions
Simulations without biomass burning emissions
Regional analysis:
- L2 data
- OMI NO2
- CALIOP data
- Soil Moisture CCI
Temperature effect on AOD
WP1: Southeastern USA
WP2: Boreal region
WP3: Impact of ADRE in the future

Project outputs

- information on the formation mechanism of natural aerosol particles

- quantitative information on the resulting change in particle concentrations and their radiative effects.

- a projection of the effect in future climate (until 2050)